

MGE-Micro Green Energy Technologies APS.

DTU Science Park

Agern Allé 5A, Bygning 23, 2970 Hørsholm

Midlertidig

Test af Generator



Titel:

Transient GeneratorTest

Institution:

MGE-Micro Green Energy Technologies ApS. DTU Science Park

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Abstract

Flywheels have been used throughout the ages to ensure the smooth operation of machines. The first purely mechanical models consisted of a stone wheel attached to an axle. Today, flywheels are complex structures where energy is mechanically stored and transferred to and from the flywheel by an integrated motor/generator. The stone wheel has been replaced by a steel or composite rotor and magnetic bearings have also been developed. Today, flywheels are used as UPS storage in various industries worldwide.

Future applications will mainly include renewable energy production.

One of the most important issues for flywheel design applicable in energy production is high efficiency, sufficient torque generation, and thus reducing total losses.

MGE ApS.'s standalone, decentralized power generation technology, which includes flywheel technology, has the characteristics that will revolutionize power production in the near future.

1. Introduction

A few hundred years ago, pure mechanical flywheels, used only to keep machines running smoothly from cycle to cycle, pioneered the industrial revolution.

A variety of shapes and designs were implemented during this time, but it was not until the early 20th century that flywheel rotor shapes and rotational stress were thoroughly analyzed. Later, in the 1970s, flywheel energy storage was proposed as a primary target for electric vehicles and stationary power backup. At the same time, fiber composite rotors were built, and magnetic bearings began to appear in the 1980s. Therefore, the potential for using flywheels as electrical energy storage has long been the subject of extensive research.

New developments in materials, magnetic bearings, and power electronics have made flywheels suitable for kinetic energy storage. Advances in power electronics, IGBTs, and FETs have made it possible to operate the flywheel at high power with a power electronics unit that is comparable or smaller in size to the flywheel itself.

High speed is desired because the energy stored in the flywheel is proportional to the square of the flywheel's rotational speed, but linearly proportional to its mass. However, the stored energy can be released by generating the torque required by the alternator.

Flywheels have a number of features that make them useful for storing and releasing kinetic energy. They have high power and energy density.

There is no capacity degradation.

They are suitable for scalable technology.

Environmentally friendly materials, low environmental impact.

High power, suitable for applications from kilowatts to gigawatts. Each machine can be designed to suit the physical conditions of the load.

Theoretical approach to flywheel energy generation system

1.1. Energy storage in flywheels

A flywheel stores energy in a rotating mass. Depending on the inertia and speed of the rotating mass, a certain amount of kinetic energy is stored as rotational energy. Drive Motor, electrical energy given to the stator winding is converted into torque and applied to the flywheel/rotor, causing the flywheel/rotor to rotate faster and gain kinetic energy.

The kinetic energy stored in the flywheel/rotor applies high torque, which is converted into electrical energy in the alternator. In addition to the flywheel, additional power electronics are required to control power input and output, speed, frequency, etc.

The kinetic energy stored in a flywheel is proportional to the mass and the square of the rotational speed according to Equation (1).

Equation 1:

$$E_k = \frac{1}{2} I \omega^2 \quad (1)$$

where E_k is the kinetic energy stored in the flywheel, I is the moment of inertia, and ω is the angular velocity of the flywheel. The moment of inertia for any object is a function of its shape and mass. For steel rotors the dominant shape is a solid cylinder, giving the following expression for I :

Equation 2:

$$I = \frac{1}{2} m r^2 \quad (2)$$

where r is the radius and a is the length of the cylinder, m is the mass of the cylinder, and ρ is the density of the cylinder material. The other dominant shape is a hollow circular cylinder, which approximates a composite or steel rim attached to a shaft by a web, which is given by Equation (3).

Equation 3:

$$I = \frac{1}{2} m r^2 \quad (3)$$

Equation (1) shows that the most efficient way to increase the stored energy is to accelerate the flywheel. The speed limit is determined by the stress developed in the wheel due to inertial loads, called the tensile strength s . Lighter materials develop lower inertial loads at a given speed, so composite materials with low density and high tensile strength are excellent for storing kinetic energy. The maximum energy density by volume and mass, respectively, are:

Equation 4 :

$$\text{ev } 1/4 Ks=r \text{ içinde } 1/4 Ks \quad (4)$$

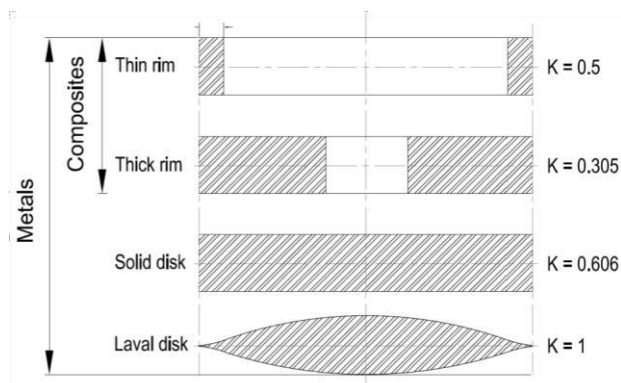
unit volume or mass, respectively, K is the shape factor, s is the maximum stress in the flywheel, and r is the mass density. In the case of plane stress, if the height of the disk is small compared to the diameter and a homogeneous isotropic material with a Poisson's ratio of 0.3, i.e. steel, is used, the K factors are given in Table 1.

In a three-dimensional object, there will be a three-dimensional interaction of material stresses. For a rotor made of an anisotropic material such as a fiber-reinforced composite, this stress interaction will limit the practical dimensions possible. Considering the safety issues, the resulting flywheel design is based on a hollow cylinder in which the material stresses created by the three-dimensional effects are minimized.

In short, the designs are,

Figure 1

Shape factor K for different plane stress geometries.



The two stresses of primary concern are radial stress and hoop stress, Figure 2. For an isotropic material the radial stress is expressed by Equation (5).

Equation 5:

$$SR \frac{1}{4} \beta v_{22} R_2^2 \quad (5)$$

$$\frac{8}{r_0} \beta r_i r_2$$

ρ is the mass density, ω is the rotor speed, ν is the Poisson's ratio, r_0 is the outer radius of the rotor, r_i is the inner radius of the rotor and r represents any radius inside the rotor.

The hoop tension is expressed by Equation (6).

Equation 6:

$$\sigma_r = \frac{3 + \nu}{8} \rho \omega^2 (r_0^2 + r_i^2 - r^2) - \frac{1 + 3\nu}{4} \rho \omega^2 r^2 \quad (6)$$

Table 2 shows the properties for common rotor materials.

Most designs allow for a 50% rotational speed reduction, so the available energy is 75% of the stored energy, i.e. the discharge depth is 75%. In general, the flywheel geometry and speed determine the energy storage capacity, while the drive motor, generator and power electronics determine the power capacity.

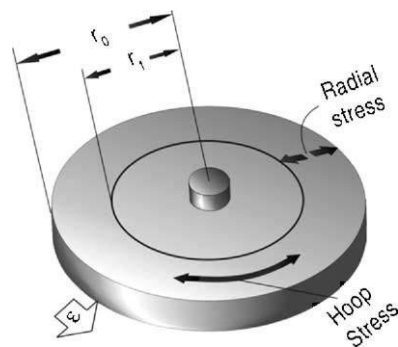


Figure 2. Radial and hoop stress in a cylinder rotating around its axis with angular velocity ω .

Table 2: Data for different rotor materials

Material	Density (kg/m ³)	Tensile Strength (MPa)	Maximum energy intensity (for 1kg)	Cost (\$/kg)
Monolithic material 4340 Steel Composite	7700	1520	0.19MJ / kg 1/4 0.05kWh / kg	1
E-cam	2000	100	0.05MJ / kg 1/4 0.014kWh / kg	11.0
S2-cam	1920	1470	0.76MJ / kg 1/4 0.21kWh / kg	24.6
Carbon T1000	1520	1950	1.28MJ/ kg 1/4 0.35kWh/kg	101.8
Carbon AS4C	1510	1650	1.1MJ / kg 1/4 0.30kWh / kg	31.3

1.1. Drive Motor and Alternator

Basically, energy storage in flywheels is activated by the drive motor. The drive motor is generally preferred as an asynchronous motor. IM asynchronous motors have high torque power. However, PM motors developed in recent years provide higher torque but are more expensive in terms of cost.

However, the drive motor selection can be preferred in accordance with the flywheel geometry, K value and capacity selection.

Alternators, on the other hand, demand inversely proportional torque under load and depending on the rpm relationship. In short, the alternator efficiency constant within the system components is 95.5 Nm with a rotation speed of 100 RPM for 1 kW energy production within friction losses.

The equation is calculated per as Tork $T = F \times d$

Based on this equation, the torque constant is determined as 95.5 Nm for 1kW/100RPM.

1. Test af generator

1.1. Introduction of the generator system:

1. The generator to be tested is a 1 MWh system without any fuel input.

2. Main components of the system;

a. Driver motor: 90 kWh power, 2950 rpm asynchronous electric motor,

b. Flywheel 1: A Ø 900mm H 200 mm and 996 kg flywheel designed to increase the torque power of the engine,

c. Reducer: A 2:1 gear box to increase the torque given by the driver motor and Flywheel 1 and to decrease the rotation speed of the engine shaft,

d. Flywheel 2: A Ø 1450 mm H 200 mm and 2576 kg flywheel designed to provide the torque demanded by the 1250 kVA alternator used in the system, with the increased torque power by the driver motor, flywheel 1 and reducer.

e. Alternator: a 1250 kVa alternator that converts the kinetic energy generated by the drive motor flywheels and reducer into electrical energy,

f. Battery group: a 1400 Amp battery group that provides the electrical energy required for the drive motor,

g. Inverters: Inverters that convert the DC energy received from the battery group into 400V AC,

h. Rectifier: a Rectifier required to keep the battery group at a constant 48 volt level, i. Electrical panel: a panel required for system control,

The generator system consists of the equipment outlined above.



1.1. Theoretical approach to the MGE Generator System.

The 1st law of thermodynamics states that energy cannot be created or destroyed. There is no claim to CREATE ANY AMOUNT OF ENERGY in this system.

Work = force × distance

$$W = F \times \diamond$$

We know the four basic forces as electromagnetic, gravity, weak nuclear and strong nuclear. The cornerstone of the developed generator system is based on the storage of gravity force in flywheels.

The developed generator system is the application of the flywheel energy storage system, the theoretical approach of which is given above, of the gravity force.

1.1. Test

The generator system developed by MGE-Micro Green Energy Technologies ApS. was conducted to determine whether the equality in the INPUT-OUTPUT balance was disrupted.

As stated in Section 2.2., the 1st law of Thermodynamics in the MGE generator system states that energy cannot be created or destroyed. There is no claim to CREATE ANY AMOUNT OF ENERGY in this system.

However, the reason for the disruption of the INPUT-OUTPUT equality and the positive distortion of the OUTPUT is that the gravity force can be stored in the flywheels and additional energy can be produced.

1.1.1. Test method

Before the MGE Generator System, the calibrations of all measurement devices were renewed and the error margins were kept in the range of +, - 0.0001 -0.0005, thus minimizing the measurement errors.

Measurements were made at two points.

1. In the battery group with 1400 Amp current and 48 Volt voltage feeding the driver motor,
2. The power generated in the alternator was connected to the load bank containing a graded resistor, It was made at the point.

1.1.2. Test system

1. The energy taken from the battery group is converted to 380 V AC voltage and loaded into the 90 kWh drive motor.
2. The activated system is gradually controlled with the drive motor control and the drive motor shaft rotation speed is ensured to reach 2900 Rpm.
3. The 2900 RPM rotation speed on the drive motor shaft provides a total torque of 2239 Nm with the solution made with the equation 1 given in section 1.1. The torque power of the drive motor and 1. Flywheel.
4. The reducer 2:1 reduces the drive motor speed and creates approximately 4450 Nm torque.
5. The 1250 kVa alternator needs approximately 9559 Nm torque at 1500 RPM.
6. The 4450 Nm section of the 9559 Nm torque demand is provided by the drive motor 1. Flywheel and speed reduction and equipment up to the reducer output.
7. The 2nd flywheel mounted on the alternator shaft after the reducer output completes the necessary missing torque forc



2. Measurement results

Before the generator system is activated, the battery group voltage values are measured.

Battery group voltage: 52 V

The generator system is activated, the voltage values on the battery group are recorded by the data log once every 5 seconds.

Each 100 kWh resistance group of the load bank connected to the alternator output is activated in turn. The voltage of the battery group is monitored as each resistance group is activated.

In the test study, all 10 100 kWh resistance groups are gradually activated.

The voltage values of the battery group during the test operation lasting 2 hours and 45 minutes;

1. Under 100 kWh load for 15 minutes, Battery group voltage; 52 V
2. Under 200 kWh load for 15 minutes, Battery group voltage; 52 V
3. Under 300 kWh load for 15 minutes, Battery group voltage; 52 V
4. Under 400 kWh load for 15 minutes, Battery group voltage; 52 V
5. Under 500 kWh load for 15 minutes, Battery group voltage; 52 V
6. Under 600 kWh load for 15 minutes, Battery group voltage; 52 V
7. Under 700 kWh load for 15 minutes, Battery group voltage; 52 V
8. Under 800 kWh load for 15 minutes, Battery group voltage; 52V
9. Under 900 kWh load for 15 minutes, Battery group voltage; 52V
10. Under 1000 kWh load for 30 minutes, Battery group voltage; 52V

Evaluation

Both theoretical and practical test studies conducted on the MGE generator system have shown that the energy need, which is indispensable for humanity, can be provided with different production methods.

The developed MGE generator system does not violate the laws of thermodynamics.

We find it useful to repeat; There is no claim to CREATE ANY AMOUNT OF ENERGY in this system. The MGE generator system operates in accordance with the 1st Law of thermodynamics.

The input of the MGE generator system is basically the GRAVITY FORCE.

3. NOTE

This study was prepared as a temporary report upon the request of MGE-Micro Green Energy Technologies ApS. Extensive theoretical studies and measurements should be carried out on the MGE generator system.

The temporary test report was written and given to the MGE institution that requested the report, with a limited usage record. The temporary test report should be given to 2nd persons and institutions other than MGE.



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